Edge Magnetic Topology Change Induced by LHCD and Its Profound Effects in EAST

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The challenge of fusion research and technology is to confine a burning plasma while having tolerable continuous and transient heat and particle fluxes on the plasma facing components. Experimental results demonstrate the edge magnetic topology plays a key role in the dependence of the plasma confinement, the edge MHD stability and the interaction between plasma and the first wall, particularly with the divertor [1, 2]. By applying Resonant Magnetic Perturbations (RMPs) induced by a set of in-vessel coils at the plasma edge, one can influence the edge pedestal transport, as well as the periodic transient power loads due to the Edge Localized Modes (ELMs) [1]. However, in future fusion reactors in-vessel perturbation coils may not be feasible.

On EAST [3], Low Hybrid Current Driven (LHCD) appears to induce a profound change in the edge magnetic topology by driving currents near the plasma edge, evident by the non-rotating Helical Current Filaments (HCFs) flowing along the magnetic field lines in the Scape Off Layer (SOL) as seen in Fig. 1. The magnetic perturbation generated by these HCFs has been measured by the pick-up coils during a modulation of LHCD, see Fig. 2. These measured magnetic fluctuations have both poloidal and toroidal dependence, indicating a 3D distortion of the plasma edge topology due to the formation of HCFs.

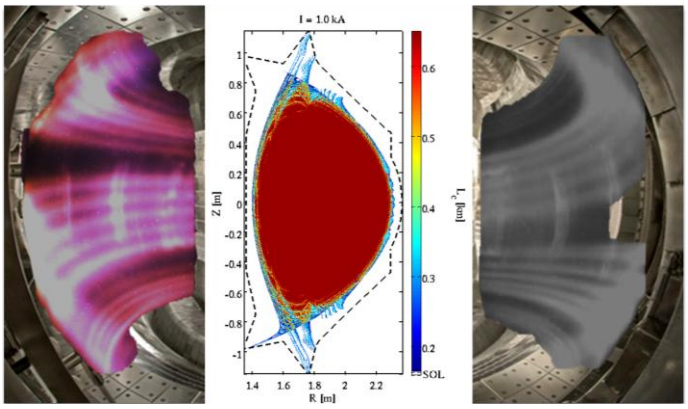

Figure 1:(left and right) Five non-rotating helical radiating belts induced by LHCD driving currents in the plasma edge; (middle) Connection length plot of the poloidal cross-section at $\varphi = 0^{\circ}$ of EAST discharge #29100 at 3.5s with modelled HCFs. The plasma images were measured by two visible cameras viewing different sides of the EAST torus.

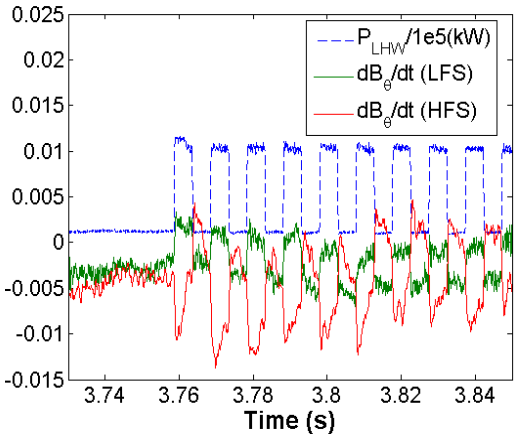

Figure 2: Time evolution of the LHCD power modulated at 200 Hz and magnetic fluctuations measured by pickup coils at the low and high field sides of EAST for discharge #41748.

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The edge HCFs lead to splitting of divertor strike points (SP) with similar effects to the RMPs, as manifested in the heat and particle flux profiles, see Fig. 3. The heat flux profile shows a distinct splitting of the original strike point, while the influence of HCFs on the particle flux profile is not as pronounced. The splitting of the SP depends on the edge safety factor, plasma density, as well as the toroidal angle, and was not observed in either the Ohmic or ICRF plasmas.

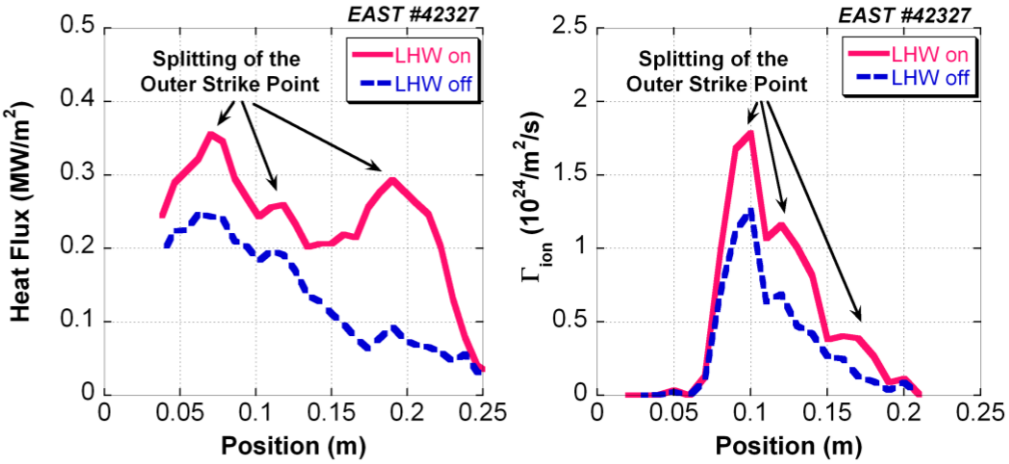

Figure 3: The heat (left) and particle (right) flux distributions along the outer divertor plate for a plasma current of 450 kA with and without LHCD for discharge #42327.

The influence of HCFs on the characteristics of ELMs has been studied through modulation of the LHCD power in ICRH dominated H-mode plasmas. In this experiment the LHCD power was set at 1.3 MW and modulated at 10 Hz with a 50% duty cycle. Thus the duration of the LHCD off phase is 50 ms which is half the energy confinement time. Without LHCD the ELM frequency is fairly regular at ~150 Hz. When LHCD is applied the ELMs disappear or sporadically appear with higher frequency ~600 Hz as seen in Fig. 4. In addition, a drop in the pedestal density profile has been observed during LHCD application.

The change in edge magnetic topology has been qualitatively modelled by including the HCFs in a field line tracing code (Fig. 1 centre). The connection lengths of the magnetic field lines are calculated using an experimental equilibrium superimposed with a vacuum field from HCFs with a total measured filament current of a few hundreds A. The results show a strong modification of the plasma edge topology dependent on the edge safety factor as well as the amplitude of currents flowing in these filaments. The fields produced by the HCFs form several lobes with long connection length field lines near the X-point which can hit the outer divertor plate resulting in splitting of the SP. This can qualitatively explain the experimental observations of SP splitting.

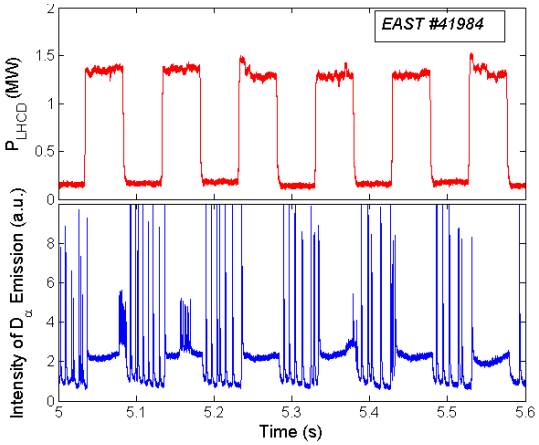

Figure 4: The effect of modulating the LCHD power on ELMs indicated by the D_α emission measured from the outer divertor.

References:

[1] T. Evans, *et al.* Nature Phys. 2, 419 (2006).
[2] Y. Liang, *et al.* Phys. Rev. Lett. 98 265004 (2007).
[2] B. N. Wan, *et al.*, in this conference.

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